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Report of the ICES/GLOBEC Working Group on Cod and Climate Change (WGCCC)

By correspondence

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Executive Summary

WGCCC has worked by correspondence during 2006/2007. The principal activity of the programme in 2006 was the Workshop on Decline and Recovery of North Atlantic Cod Stocks (WKDRCS), while in 2007 it is the Workshop on the Integration of Environmental Information into Fisheries Management Strategies and Advice, which had not yet met at the time this report was written. Progress is reported here on new scientific findings, on meetings during the past year and on the activities of the ICES/GLOBEC coordinator.

Scientific highlights

A Group paper on Decline and Recovery of cod, synthesising the results of the WKDRCS workshop, uses among-stock comparisons to illustrate that fishing has played a dominant role in the dynamics of cod stocks, but variability in climate has contributed to variability in recruitment, individual growth and natural mortality (Lilly *et al.*, in press). A cooling event during the last three decades of the 20th century contributed to the rapid decline of several stocks in the Northwest Atlantic, while changes in life-history traits (growth rate, age at maturity) and the biotic environment (predators and prey) may be contributing to slow recovery.

As part of the preparation for WKDRCS the ICES/GLOBEC coordinator prepared and subsequently published a study on 15 cod stocks across the North Atlantic focussing on the role of changes in weight-at-age in determining changes in total stock biomass (Brander, 2007c). It is shown that most declines and recoveries of cod stocks since 1970 have been accompanied or preceded by changes in weight-at-age. The causes of these changes in weight-at-age may be an important component of understanding why total biomass fluctuates.

CCC members have, by means of statistical modelling, studied the connection between the North Atlantic Oscillation (NAO) and recruitment to 22 cod stocks. For the first time one overall model is applied. Results of the analysis demonstrate (i) a geographic pattern in the effect of the NAO on recruitment, which resembles the geographic pattern of the correlation between the NAO and sea surface temperature, and (ii) temporal trends in the effects of climate (Stige *et al.*, 2006).

1 Terms of reference

The **ICES/GLOBEC Working Group on Cod and Climate Change** [WGCCC] (Co-Chairs: Geir Ottersen, Norway and Kai Wieland, Greenland) will work by correspondence in 2006–2007. The Terms of Reference (ICES CM 2006/OCC:11) are:

a) review, evaluate and develop results from the Workshop on the Decline and recovery of cod stocks throughout the North Atlantic including tropho-dynamic effects;

b) plan the Workshop on the Integration of Environmental Information into Management Strategies and Advice (WKEFA, ACFM) in 2007;

c) initiate plans for the Workshop on Cod and Future Climate Change, which is postponed to 2008;

d) initiate plans for a Synthesis workshop or Theme Session in 2009.

WGCCC will report by 15 May 2007 for the attention of the Oceanography Committee, ACE, and ACFM.

2 Review of past and ongoing activities

2.1 Workshop on Decline and Recovery of North Atlantic Cod Stocks (WKDRCS)

The most recent in the series of workshops carried out by CCC focused on the topic of Decline and Recovery of North Atlantic Cod Stocks. It was held in St John's, Newfoundland in 9–12 May 2007 and co-convened by George Lilly, Canada, Brian Rothschild, USA, Svein Sundby, Norway and Kai Wieland, Greenland. 19 scientists from eight different countries participated.

Cod have been subjected to changes in climate and fishing intensity for centuries, but detailed information on declines and recoveries comes mainly from the past 30–40 years, which is a short time span relative to many natural phenomena. All stocks, with the exception of the Celtic Sea, have suffered prolonged periods of decline since 1970. Comparison between NW and NE Atlantic stocks reveals two major differences: (i) most NW Atlantic stocks share a pattern of increase and decline in biomass, whereas the NE Atlantic stocks do not, and (ii) although fishing mortality is generally higher on NE than on the NW Atlantic cod stocks, the declines in biomass were much greater in the NW Atlantic than in the NE. The principal reason for the non-recovery of NW Atlantic cod stocks is probably reduced productivity compared with the time before the collapse, due to increased natural mortality, slower growth rate and lower recruitment rate. In addition there is still some fishing mortality in directed and non-directed fisheries.

A full report on the outcome of the workshop was published as ICES CM2006/OCC:12 156pp, available at http://www.ices.dk/globec). The Executive Summary is given in Annex 1. Results of the workshop are also described in the GLOBEC Newsletter Vol. 12, No.

2.2 Group paper on Decline and Recovery of cod

This paper is a synthesis of the results of WKDRCS, co-authored by all participants with G.R. Lilly as lead author and presented at the Lowell Wakefield Fisheries Symposium on Resiliency of Gadid Stocks to Fishing and Climate Change Anchorage, Alaska, USA, 31 October–3 November 2006 (Lilly *et al.*, in press). Several CCC members participated at this symposium.

2.3 The ECONORTH symposium

A number of WGCCC scientists from both sides of the Atlantic participated. The foci of the symposium were: 1) Bottom up vs top-down effects on ecosystems, 2) Resilience of feeding habitats and major trophodynamic pathways, 3) Behaviour/Life-histories/Reproduction strategies, 3) Recruitment processes, 4) Climatic effects on food webs, 5) Coupled processes between physics and biology, 6) Mechanisms for large-scale changes and future directions in platforms to reveal food-web dynamics. More than 120 contributions were presented, a selection of the contributions has been submitted to Deep-Sea Research and the accepted papers will be issued in a symposium volume.

2.4 Progress with the WGCCC book

At the 2000 WGCCC Meeting (ICES CM 2000/C:11) it was decided that a major component of the WGCCC synthesis activities would be the publication of a book on cod. At the 2002 Meeting (ICES CM 2002/C:15) an outline including specific chapters was adopted and lead co-authors were suggested with K. Brander and K. Drinkwater agreeing to be the co-editors. In 2003, a Synthesis Workshop was held (ICES CM 2003/C:10) to discuss in detail what each of the chapters would cover, to coordinate the chapters, and to agree upon formats, audience, publication, and a timetable.

The editors have received good draft versions of nearly all chapters. Unfortunately, delivery of manuscript to the publisher has been substantially delayed due to late submission of drafts of the remaining couple of chapters and the heavy workload on the editors on other prioritized elements of their work programme. Since reviews, editorial suggestions and rewriting will take time, the final publication date will not be before 2008.

2.5 Update on ICES/GLOBEC position and secretariat

Limited funding meant that the salary of the coordinator was again reduced in 2006. A brochure was circulated to ICES delegates and committee chairs in September 2006 to ask for their assistance in identifying funding organisations (e.g. national research councils) to which an application for an international project office such as this can be made, but did not elicit any response. The existing funding from UK, Denmark, France and Norway continues.

The principal activity in the programme in 2006 was the workshop on Decline and Recovery of Cod Stocks, which generated several publications and working documents and also much public interest in Newfoundland, where it was held. The Consultative Committee and the Science Committees acted to stimulate greater efforts on the application of information from programmes such as GLOBEC to fisheries management and this resulted in the establishment of a workshop on Application of Environmental Information in Fisheries Management, which the coordinator is supporting in 2007. A GLOBEC workshop on Climate Variability and Marine Ecosystems in September 2006 generated a number of papers, which have been accepted, including (Brander, 2007b; Jenning and Brander, 2007; Perry *et al.*, 2007). The IPCC process took a substantial amount of the coordinator's time in revising the sections on fisheries and the marine system in the chapters on Food (ch 5), Observed Impacts (ch 1) and Ecosystems (ch 4). The full IPCC report will be published shortly and a paper in PNAS Special Theme on Global Climate Change and Food Security has been accepted (Brander, 2007a). Some time was spent on the Fisheries Induced Adaptive Change programme: attending the annual project meeting (including a talk at the training programme), advertising and selecting a candidate for the post-doctoral position and hosting a meeting of the appointed researchers. Unfortunately the ICES participation was terminated due to disagreement over the appointment of the post-doc and concern over the narrow scientific viewpoint which the programme was adopting.

The coordinator presented a review of Climate Related Research in ICES and a proposed workplan for the period to the end of 2009 to the Consultative Committee in May 2007. It will be discussed by the ICES Bureau and a decision will be made on whether the ICES/GLOBEC office will continue after the end of 2007.

Results and knowledge gained from the Cod and Climate Change programme are being presented and applied extensively by scientists whose work is not funded from the programme office budget, as well as by the coordinator.

3 Future WGCCC activities

3.1 Workshop on the Integration of Environmental Information into Fisheries Management Strategies and Advice

A Workshop on the Integration of Environmental Information into Fisheries Management Strategies and Advice [WKEFA] (Co-chairs: Manuel Barange, UK, and John Simmonds, UK) met at ICES Headquarters, Copenhagen, Denmark, from 21–22 February 2007 for a scoping meeting and will meet for the main meeting 18–22 June 2007 This workshop was initiated by CCC and focuses directly on action item 1) in our Strategic Plan. The objective is to identify methodology to operationalize the use of environmental information for the improvement of fisheries management advice. The main approach is to take case studies which have consequences for medium-term and short-term influence in management. The ICES resolution and Terms of Reference for WKEFA is appended in Annex 2.

3.2 Workshop on the Future of Cod in a Changing Climate (ToR)

The WGCCC proposes that the **Workshop on Cod and Future Climate Change** will be held in spring 2008 (instead of 2007 as envisaged in the CCC Strategic Plan to avoid having two workshops in 2007) under the chairmanship of K. Drinkwater (Norway) and N.N. (yet to be decided). Dr K. Drinkwater presented a first outline of the workshop at last years meeting. A recommendation in preliminary form is included in Chapter 4.

3.3 Synthesis II ICES ASC Theme session or Workshop

The WGCCC Strategic and new Action Plan outlines plans for a Synthesis II Workshop. At last years meeting it was suggested that an ICES ASC theme session may be held in 2009 rather than a workshop. The group decided to postpone any detailed discussion on this.

4 Recommendations and draft resolutions for future meetings

Recommendation I – WGCCC meeting 2008

The **ICES/GLOBEC Working Group on Cod and Climate Change** [WGCCC] (Co-Chairs: G. Ottersen, Norway and K. Wieland, Greenland) will tentatively meet in spring 2008 in connection with the Workshop on Cod and Future Climate [venue and dates to be decided] to:

a) review and evaluate the Workshop on the Integration of Environmental Information into Fisheries Management Strategies and Advice [WKEFA]

b) review and evaluate the Workshop on the Decline and Recovery of Cod Stocks Throughout the North Atlantic including trophodynamic effects [WKDRCS];

c) review and evaluate the progress on the publication of the WGCCC book

d) make final preparations for the a Workshop on Cod and Future Climate Change

e) continue planning for a WGCCC Synthesis Theme Session at ICES ASC 2009;

WGCCC will report by 15 May 2008 for the attention of the Oceanography Committee.

Supporting Information

PRIORITY:	This Group is of fundamental importance to the future of the ICES Advisory Process.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	The work will be carried out to review past activities and plan future Workshops and Theme Sessions. a) WKEFA will be held in June 2007. It deals directly with item 1 in the WGCCC Action plan. The outcome of the workshop will be evaluated and it will be decided if the report should be published as a CRR. b) WKDRCS was held 9-12 May 2007 and a report has been published. The workshop deals with items 3 and 5 in the WGCCC Action plan. The outcome will be evaluated and it will be decided if the report should be published as a CRR. c) One of the major components of the synthesis planned by the WGCCC is the publication of a book on cod. A lot of good material has been written, but some missing chapters are still delaying the process. An update will be provided. d) The final preparations for the Workshop on Cod and Future Climate Change will be carried out. It deals directly with item 4 in the WGCCC Action plan. e) The planning of a final Synthesis Theme Session at ICES ASC 2009 will continue
RESOURCE REQUIREMENTS:	Assistance of the ICES/GLOBEC Coordinator in maintaining and ex-changing information via the web site, Newsletters, databases and workshop bulletin boards.
PARTICIPANTS:	This WG meeting is expected to attract 15-20 participants.
SECRETARIAT FACILITIES:	None
FINANCIAL:	None
LINKAGES TO ADVISORY COMMITTEES:	Relevant to the work of the ACFM and ACE.
LINKAGES TO OTHER COMMITTEES OR GROUPS:	Living Resources, SGNARO, WGZE, WGRP, WGBPI.
LINKAGES TO OTHER ORGANIZATIONS:	GLOBEC is a co-sponsor of WGCCC.

Recommendation II – Draft resolution to hold a Workshop on cod and future climate change

The WGCCC proposes that

A **Workshop on Cod and Future Climate Change [WKCFCC] (Co-Chairs:** K. Drinkwater (Norway) and N.N**)** will meet in spring 2008 (instead of 2007 as envisaged in the CCC Strategic Plan; date and venue yet to be decided) to:

In response to future climate change scenarios

a) to determine the most likely response of the physical oceanography, including nutrient concentrations, in the North Atlantic;

b) to develop impact scenarios for phytoplankton and zooplankton production and distribution, especially those species eaten by cod and their predators or prey during their life histories;

c) to determine the most likely response of the prey or predators of cod including the forage fishes, such as capelin, herring, sprat and mackerel;

d) to develop future scenarios for cod production (growth, reproduction, mortality, recruitment) and distribution.

This will be carried out using a combination of retrospective data analyses and a variety of modelling approaches. The Workshop report will be presented to the Oceanography Committee at the 2008 ICES Annual Science Conference.

Supporting Information

PRIORITY:	This Workshop will contribute to the Cod and Climate Change strategic plan.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	The Workshop will contribute to Goals 1, 4, 5 and 10 of the ICES Strategic Plan Many of the regions presently occupied by Atlantic cod are predicted to undergo significant warming in response to climate change and in recent years much of the North Atlantic has experienced such warming. Increasingly, managers, politicians and the general public have been asking what will be the impacts of future climate change. Such information for cod and the marine ecosystems have been limited. Indeed, the few published studies have usually considered the response of individual species to increased warming without considering other components of the marine ecosystem, such as their prey or predators. However, climate change is expected to impact both the structure and function of marine ecosystems and to develop more plausible impact scenarios we must consider the species as part of the ecosystem. Using our increased understanding gained through the ICES/GLOBEC Cod and Climate Change program, including past workshops, plus other research on the effects of climate variability on cod and its supporting ecosystem, the impact of future climate scenarios on the marine ecosystems of the North Atlantic and especially cod will be developed.
RESOURCE REQUIREMENTS:	Assistance of the ICES/GLOBEC Coordinator in maintaining and exchanging information and data to potential participants.
PARTICIPANTS:	This Workshop is expected to attract 15-25 participants, most of who would contribute papers. The majority will be drawn from the ICES scientific community, although a number of scientists from outside ICES are also expected to contribute.
SECRETARIAT FACILITIES:	None
FINANCIAL:	None
LINKAGES TO ADVISORY COMMITTEES:	Relevant to the work of the ACFM and ACE.
LINKAGES TO OTHER COMMITTEES OR GROUPS:	Living Resources, SGNARO, WGZE, WGRP, WGBPI.
LINKAGES TO OTHER ORGANIZATIONS:	GLOBEC is a co-sponsor of the workshop.

References

Brander, K. M. 2007a. Global Fish Production and Climate Change. Proceedings of the National Academy of Science, accepted.

Brander, K. M. 2007b. Impacts of climate change on fisheries. Journal of Marine Systems, accepted.

Brander, K. M. 2007c. The role of growth changes in the decline and recovery of North Atlantic cod stocks since 1970. ICES Journal of Marine Science, 64: 211-217.

Brander, K. M. 2007d. Fisheries and Climate. In Encyclopedia of Ocean Sciences, online edition. Edited by J. H.Steele, K. K.Turekian, and S. A.Thorpe., accepted, Elsevier.

Jennings, S., and Brander, K. M. 2007. Predicting the effects of climate change on marine communities and the consequences for fisheries. Journal of Marine Systems, accepted.

Lilly, G. R., Rothschild, B., Sundby, S., Wieland, K., Brander, K., Ottersen, G., Drinkwater, K. *et al*. 2007. Decline and recovery of Atlantic cod (*Gadus morhua*) stocks throughout the North Atlantic. Proceedings of the 24th Lowell Wakefield Fisheries Symposium . In press.

Perry, R. I., Cury, P., Brander, K. M., Jennings, S., Möllmann, C., and Planque, B. 2007. Sensitivity of Marine Systems to Climate and Fishing: concepts, issues and management responses . Journal of Marine Systems, accepted.

Stige, L. C., Ottersen, G., Brander, K., Chan, K.-S., and Stenseth, N. C. 2006. Cod and climate: effect of the North Atlantic Oscillation on recruitment in the North Atlantic. Marine Ecology Progress Series, 325: 227–241.

Annex 1: Summary for WKDRCS

Atlantic cod (*Gadus morhua*) stocks respond to long-term climate changes, such as the warming of the North Atlantic during the 1920s and 1930s, when cod increased rapidly in abundance off West Greenland and spread far to the north. At the same time there was increased recruitment at Iceland and increased abundance and northward expansion in the Barents Sea. By the time that the waters at West Greenland cooled in the late 1960s, the cod stock biomass had declined greatly from its peak in 1949. Both climate and the fishery contributed to the subsequent collapse of the stock, but it is not possible to make a quantitative attribution and the factors interact. In this and other cases the effective environmental factors include plankton production and other ecosystem effects. These factors often co-vary with temperature change, making it difficult to separate them from direct effects of temperature on growth, survival and recruitment.

Cod have been subjected to changes in climate and fishing intensity for centuries, but detailed information on declines and recoveries comes mainly from the past 30–40 years, which is a short time span relative to many natural phenomena. All stocks, with the exception of the Celtic Sea, have suffered prolonged periods of decline since 1970. Comparison between NW and NE Atlantic stocks reveals two major differences: (i) most NW Atlantic stocks share a pattern of increase and decline in biomass, whereas the NE Atlantic stocks do not, and (ii) although fishing mortality is generally higher on NE than on the NW Atlantic cod stocks, the declines in biomass were much greater in the NW Atlantic than in the NE. Directed fishing was halted during the early 1990s for all NW Atlantic shelf stocks from the eastern Scotian Shelf northward. All these stocks have since been characterized by low productivity, and several have shown no sign of recovery after more than a decade without directed fishing. The NW Atlantic stocks from the eastern Scotian Shelf northward inhabit areas with average temperatures below 4 $^{\circ}$C and in all of them the mean weight-at-age began a period of decline before the biomass declined. The NE Atlantic stocks all inhabit areas with average temperatures above 4 $^{\circ}$C and showed less variability in mean weight-at-age.

Both fishing and climate are implicated in the declines in cod stock biomass since 1970. In the NW Atlantic the fishing mortality increased until moratoria were imposed in the early 1990s. The decline in biomass was caused by fishing, but changes in the productivity of the stocks contributed to the collapse and there is good evidence that the decline in biomass also caused fishing mortality to increase. Fisheries management must be sensitive to possible changes in stock productivity and must either respond quickly, to prevent increased mortality and further stock decline, or regulate fishing in a precautionary way, which is robust to uncertainties about stock productivity.

Changes in weight-at-age are an important component of the variation in productivity of coldwater cod stocks. Variation in weight-at-age appears to be mainly due to changes in the environment. In the S. Gulf of St. Lawrence density-dependent growth and changes in the direction of size selective fishing mortality appear to be the most important factors and here size-at-age has remained low despite good conditions for growth and low fishing mortality. Age and size at maturity have declined in many stocks and there appears to be a genetic component to this change, in response to fishing (where it has been investigated – Arcto-Norwegian cod, S. Labrador, S. Gulf of St Lawrence). Early maturity gives a selective advantage under most high mortality regimes, but reduces population productivity if fishing mortality is reduced. The reversion to older ages and larger sizes at maturity will be slow if additive genetic variance has been depleted.

The risk of stock collapse increases when stock productivity declines. Some of the life-history characteristics (growth and maturation in particular) governing productivity can be monitored by sampling commercial and research catches and may give timely indications of changes in

productivity and risk of collapse. In order to develop their routine use in assessing risk of collapse under different fisheries management strategies, indicators of possible change in productivity (weight-at-age, condition, liver index, maturation reaction norms) should be investigated using tropho-dynamic, life history and risk assessment models.

Mean age and age diversity of spawners (and SSB) declined in many stocks in response to fishing. In many (but not all) stocks, this has resulted in a decline in recruitment rate. In Arcto-Norwegian and Icelandic cod resilience to climate change has been shown to decrease as mean age of spawners declined.

For all cod stocks, the kinds of prey and their abundance and availability vary over time. The boreal ecosystems and the Baltic Sea tend to have a narrower field of potential prey than the more southern ecosystems, and changes in the abundance or distribution of major forage species (e.g. capelin, herring) might cause food shortages for cod. This could lead to declines in condition and consequent reductions in reproductive output and even survival. Declines in prey availability have been implicated in declines in cod productivity that have lasted from one to several years, but such variability in prey has seldom been implicated as a major factor in cod stock declines. There have been suggestions that low abundance of prey may be impeding stock recovery in some areas, such as the offshore of eastern Newfoundland.

When cod stocks decline to very low abundance, the relative importance of factors governing dynamics and productivity can change. When a stock is relatively large, it may be able to sustain predation and maintain itself at relatively high abundance even when subjected to a fishery. However, if the stock has declined in abundance, for whatever reason, and predator populations have not declined, or may even have increased, then high predation mortality may impede or prevent recovery. Such impacts may occur via predation by pelagic fish on eggs and larvae of cod, as has been hypothesized for cod in the Baltic Sea, on the eastern Scotian Shelf and in the southern Gulf of St. Lawrence. It may also occur via predation on juvenile cod and perhaps even adult cod by larger predators such as seals, as has been hypothesized for the eastern Scotian Shelf, the southern and northern Gulf of St. Lawrence, and eastern Newfoundland.

In some stocks e.g. southern Gulf of St Lawrence, high natural mortality has replaced high fishing mortality, preventing recovery even when fishing pressure is low. No substantial increase in the biomass of Baltic cod can be expected without a change in environmental conditions favouring better recruitment (even at F_{PA}, which is 65% of the current fishing mortality). A general conclusion from the experience off eastern Canada is that humans may have limited ability to “rebuild” cod stocks that have declined to very low levels. Simply turning off directed fishing may be insufficient to promote recovery. The properties of the stocks themselves and the state of the ecosystems in which the cod are embedded may be such that the stocks remain constrained to their new levels of low abundance for a considerable time.

Annex 2: ICES resolution and terms of reference for WKEFA

A Workshop on the Integration of Environmental Information into Fisheries Management Strategies and Advice [WKEFA; 2006/2/ACFM24] (Co-chairs: Manuel Barange, UK, and John Simmonds, UK), co-sponsored by ICES, EUR-OCEANS, and GLOBEC, will be established and will meet at ICES Headquarters, Copenhagen, Denmark, from 21–22 February 2007 (scoping meeting during WGRED and AMAWGC) and 18–22 June 2007 to:

Scoping meeting

a) assemble and evaluate a small number of illustrative case studies in which environmental factors can be shown to have had a significant impact on exploited fish population dynamics, including information on the processes which may be responsible;

b) evaluate the availability of data/ information and define necessary work/ actions to be taken before the main WK

Main workshop

c) estimate the consequences of environmental variability (including "regime shifts") for the biological reference points and other measures which are currently used to guide fisheries management;

d) carry out analyses and formulate short, medium and long term integrated advice for the selected cases. Compare this with traditional methodology

e) bearing in mind possible fisheries and ecosystems objectives, identify, develop and evaluate procedures for improving fisheries management strategies and advice by including environmental information. Identify future directions and needs, including operability, to bring forward the process of incorporating ecosystem advice.

WKEFA will report by 29 June 2007 for the attention of the ACFM, ACE, Oceanography, Living Resources and the Consultative Committee (ConC).